Docket No.: 09634/000L271-US0
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Letters Patent of:
Kazuyuki Imagawa et al.

Patent No.: 7,227,996

Issued: June 5, 2007

For: IMAGE PROCESSING METHOD AND APPARATUS FOR COMPARING EDGES BETWEEN IMAGES

REQUEST FOR CERTIFICATE OF CORRECTION
PURSUANT TO 37 CFR 1.323 AND 1.322

Attention: Certificate of Correction Branch
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Upon reviewing the above-identified patent, Patentee noted typographical errors which should be corrected. A listing of the errors to be corrected is attached.

The typographical errors marked with an "A" on the attached list are found in the application as filed by applicant. Payment in the amount of $100.00 covering the fee set forth in 37 CFR 1.20(a) is enclosed.

The typographical errors marked with a "P" on the attached list are not in the application as filed by applicant. Also given on the attached list are the documents from the file history of the subject patent where the correct data can be found.

The errors now sought to be corrected are inadvertent typographical errors the correction of which does not involve new matter or require reexamination.

Transmitted herewith is a proposed Certificate of Correction effecting such corrections. Patentee respectfully solicits the granting of the requested Certificate of Correction.

The Commissioner is authorized to charge any deficiency of up to $300.00 or credit any excess in this fee to Deposit Account No. 04-0100.

Dated: September 7, 2007

Respectfully submitted,

By____________________

Flynn Barrison
Registration No.: 53,970
DARBY & DARBY P.C.
P.O. Box 770
Church Street Station
New York, New York 10008-0770
(212) 527-7700
(212) 527-7701 (Fax)
Attorneys/Agents For Applicant

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO.	:	7,227,996
APPLICATION NO.	:	10/057,756
ISSUE DATE	:	June 5, 2007
INVENTOR(S)	:	Kazuyuki Imagawa et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the face page, in field (56), under "Other Publications", in column 2, line 4, delete "CA,;" and insert - - CA; - -, therefor.

In column 12, line 27, after "ÿ ÿ" insert - - of - -.

In column 16, line 9, delete "(x, l, y + m)" and insert - - (x + l, y + m) - -, therefor.

In column 16, line 67, after "18(a)" insert - - . - -.

In column 17, line 39, after "T'y(x,y)" insert - -) - -.

In column 17, line 54, after "(-x,y" insert - -) - -.

In column 17, line 56, after "(-x,y" insert - -) - -.

In column 19, line 2, after "wherein" insert - - , - -.

In column 20, line 9, delete "comers" and insert - - corners - -, therefor.

In column 23, line 7, delete "filly" and insert - - fully - -, therefor.

In column 25, line 54, in Claim 17, after "amount" delete ":" and insert - - ; - -, therefor.

In column 27, line 5, in Claim 25, before "17," insert - - claim - -.

MAILING ADDRESS OF SENDER (Please do not use customer number below):
Joseph R. Robinson, Esq.
DARBY & DARBY P.C.
P.O. Box 770
Church Street Station
New York, New York 10008-0770

In column 27, line 10, in Claim 26, before "17," insert - - claim - -.

In column 27, line 17, in Claim 27, before "17," insert - - claim - -.

In column 27, line 28, in Claim 28, before "17," insert - - claim - -.

In column 28, line 17, in Claim 31, before "17," insert - - claim - -.

MAILING ADDRESS OF SENDER (Please do not use customer number below):
Joseph R. Robinson, Esq.
DARBY & DARBY P.C.
P.O. Box 770
Church Street Station
New York, New York 10008-0770

Darby & Darby

Issued Patent Proofing Form File#: **09634/000L271-US0**
Note: **P** = PTO Error **A** = Application Error

US Serial No.: **10/057,756** US Patent No.: **US 7,227,996 B2** Issue Dt.: **Jun. 5, 2007**
Title: **IMAGE PROCESSING METHOD AND APPARATUS FOR COMPARING EDGES BETWEEN IMAGES**

Sr. No.	P/A	Original Page	Original Line	Issued Patent Column	Issued Patent Line	Description of Error
1	A	Sheet 1 of 1 List of References cited by applicant and considered by examiner (11/15/2005)	Entry 1 Line 3 (Non Patent Literature Documents)	Page 2 Col. 2 (Other Publications)	4	Delete "CA,;" and insert - - CA; - -, therefor.
2	P	Page 26 Specification (01/25/2002)	22	12	27 (Approx.)	After "$\rho_{\gamma 0}$" insert - - of - -.
3	P	Page 34 Specification (01/25/2002)	16 (Approx.)	16	9 (Approx.)	Delete "(x, l, y + m)" and insert - - (x + l, y + m) - -, therefor.
4	A	Page 36 Specification (01/25/2002)	20 (Approx.)	16	67	After "18(a)" insert - - . - -.
5	P	Page 38 Specification (01/25/2002)	6	17	39 (Approx.)	After "T'y(x,y)" insert - -) - -.
6	A	Page 38 Specification (01/25/2002)	14 (Approx.)	17	54 (Approx.)	After "(-x,y" insert - -) - -.
7	A	Page 38 Specification (01/25/2002)	15 (Approx.)	17	56 (Approx.)	After "(-x,y" insert - -) - -.
8	P	Page 41 Specification (01/25/2002)	16 (Approx.)	19	2	After "wherein" insert - - , - -.
9	P	Page 45 Specification (01/25/2002)	9	20	9	Delete "comers" and insert - - corners - -, therefor.
10	P	Page 51 Specification (01/25/2002)	21	23	7	Delete "filly" and insert - - fully - -, therefor.
11	P	Page 8 Claims (09/19/2006)	Claim 22 Line 7	25	54	In Claim 17, after "amount" delete ":" and insert - - ; - -, therefor.
12	A	Page 11 Claims (09/19/2006)	Claim 28 Line 1	27	5	In Claim 25, before "17," insert - - claim - -.
13	A	Page 11 Claims (09/19/2006)	Claim 29 Line 1	27	10	In Claim 26, before "17," insert - - claim - -.

14	A	Page 11 Claims (09/19/2006)	Claim 30 Line 1	27	17	In Claim 27, before "17," insert - - claim - -.
15	A	Page 11 Claims (09/19/2006)	Claim 31 Line 1	27	28	In Claim 28, before "17," insert - - claim - -.
16	A	Page 12 Claims (09/19/2006)	Claim 34 Line 1	28	17	In Claim 31, before "17," insert - - claim - -.

U.S. PATENT DOCUMENTS

5,535,288	A *	7/1996	Chen et al.	382/236
5,751,856	A *	5/1998	Hirabayashi	382/232
5,781,650	A *	7/1998	Lobo et al.	382/118
5,905,807	A *	5/1999	Kado et al.	382/118
5,909,501	A *	6/1999	Thebaud	382/124
5,990,901	A *	11/1999	Lawton et al.	345/581
6,075,898	A	6/2000	Chase	
6,154,566	A *	11/2000	Mine et al.	382/219
6,195,460	B1 *	2/2001	Kobayashi et al.	382/190
6,278,791	B1 *	8/2001	Honsinger et al.	382/100
6,507,660	B1 *	1/2003	Wirtz et al.	382/103
6,529,630	B1 *	3/2003	Kinjo	382/190
2001/0014182	A1 *	8/2001	Funayama et al.	382/282
2001/0052928	A1 *	12/2001	Imagawa et al.	348/14.12

FOREIGN PATENT DOCUMENTS

JP	05-028273	2/1993
JP	06-074732	3/1994
JP	10-063847	3/1998
JP	10-171989	6/1998
JP	11328359 A *	11/1999
JP	2000-030062	1/2000
JP	2000-099717	4/2000
JP	2000-148980	5/2000
JP	2000-149029	5/2000
JP	2000-209425	7/2000
JP	2000-242787	9/2000

OTHER PUBLICATIONS

Johansson B et al.: "Detecting rotational symmetries using normalized convolution"; Sep. 3, 2000, Pattern Recognition, 2000, Proceedings, 15th International Conference on Sep. 3-7, 2000 at Los Alamitos, CA,; IEEE Comput. Soc. US, pp. 496-500, XP010533335; ISBN; 0-7695-0750-6; p. 496, Section 2: "Local orientation", continued on the first two paragraphs of p. 497.

Rosenfeld A et al.:"Digital picture processing"; 1982, Digital Picture Processing, Orlando, Academic Press, US, vol. 1, XP002246743.

T. Awakura et al, "Automatic Recognition of Road Signs"; Technical Report of IEICE PRMU98-201 (Jan. 1999) pp. 69-76.

"Face Detection and Tracking using Edge Orientation Information" by Bernhard Fröba and Christian Küblbeck, Visual Communications and Image Processing 2001, Proceedings of SPIE vol. 4310, 2001, pp. 583-594.

English Language Abstract of JP 05-028273.

* cited by examiner

IMAGE PROCESSING METHOD AND APPARATUS FOR COMPARING EDGES BETWEEN IMAGES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image processing method for detecting an object from an input image using a template image, and relates to an image processing apparatus therefor.

2. Description of the Related Art

Conventionally, a technique is well known in which a template image is pre-registered, and the position in an input image of an image similar to the template image is detected by pattern matching between the input image and the template image. However, since distorted perceptions are liable to be shaped according to the manner in which the background of the image similar to the template image is formed, Japanese Published Unexamined Patent Application No. Hei-5-28273 discloses a technique that has been developed to solve this problem. In this publication, a similarity value between the template image and the image corresponding to the template image is defined by the mathematical Formula 1.

Formula 1

Cv: Correlation coefficient (similarity value)

M: Number of pixels of template image in x direction

N: Number of pixels of template image in y direction

Sx: Derivative value of input image S in x direction

Sy: Derivative value of input image S in y direction

Tx: Derivative value of template image T in x direction

Ty: Derivative value of template image T in y direction

$$\sigma_{S0} = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Sx_{ij}^2 + Sy_{ij}^2)}$$

$$\sigma_{T0} = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Tx_{ij}^2 + Ty_{ij}^2)}$$

$$\boxed{\rho_{V0}} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Tx_{ij}Sx_{ij} + Ty_{ij}Sy_{ij})$$

$$Cv = \frac{\boxed{\rho_{V0}}}{\sigma_{T0}\sigma_{S0}}$$

In detail, an inner product (cos θ) of an angle θ between a normal direction vector of the edge of the template image and a normal direction vector of the edge of the input image is a component of the similarity value.

However, there exists a problem in that, as described later in detail, if the brightness of a background periphery of an image of an object is uneven, the positive and negative values of the inner product are reversed. This makes the similarity value unsuitable for the real image, and distorted perceptions are easily produced, thus making it difficult to obtain a desirable recognition result.

Additionally, the similarity value formula is nonlinear with respect to the normal direction vectors of the edges of the input and template images, and processing for the template image and processing for the input image must be performed simultaneously.

Further, the template image is scanned on the input image. A correlated calculation of the input image and the reference image must be performed for each scanning point. Therefore, in practicality, a resulting expansion of the amount of calculation makes real-time processing impossible.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an image processing method and an image processing apparatus capable of obtaining an accurate, clear recognition result and capable of performing high speed processing.

In an image processing method according to a first aspect of the present invention, the amount of matching between a template image and an input image is evaluated using a similarity value map. An evaluation vector is generated for each of the template and input images. The evaluation vector includes a component in which a normal direction vector of an edge of a specified image undergoes an even number of angular transformations.

With this structure, the matching therebetween is properly evaluated with no influence on the similarity value even in a case in which the positive and negative of an inner product (cos θ) of an angle θ between a normal direction vector of the edge of the template image and a normal direction vector of the edge of the input image are reversed by unevenness in the brightness of its background.

An image processing method according to a second aspect of the present invention includes a step of inputting a specified image for each of a template image and an input image and calculating a normal direction vector of an edge of the specified image; a step of generating an evaluation vector from the edge normal direction vector; a step of subjecting the evaluation vector to an orthogonal transformation; a step of performing a product sum calculation of corresponding spectral data for each evaluation vector, which has been subjected to orthogonal transformation, obtained for the template image and input image; and a step of subjecting a result of the product sum calculation to an inverse orthogonal transformation and generating a map of similarity values; in which a formula of the similarity values, the orthogonal transformation, and the inverse orthogonal transformation each have linearity.

With this structure, a Fourier transformation value of the template image and a Fourier transformation value of the input image do not need to be simultaneously calculated. In other words, the Fourier transformation value of the template image is obtained prior to that of the input image, thus making it possible to lighten the processing burden and improve processing speed.

An image processing method according to a third aspect of the present invention includes a step of compressing each evaluation vector, which has been subjected to the orthogonal transformation, so as to reduce the processing amount.

With this structure, what is processed is limited only to an effective component (e.g., low-frequency component). Thereby processing speed is improved.

In an image processing method according to a fourth aspect of the present invention, for the template image, the steps taken until the evaluation vector that has been subjected to the orthogonal transformation is compressed are executed before the input image is input, and the result is stored in a recording unit.

With this structure, processing relating to the template image is completed merely by reading from the recording unit, and processing speed is improved.

Formula 10

Edge normal direction vector of input image

$$\vec{I}=(I_X,I_Y)$$

I_x: Derivative value of input image in x direction

I_y: Derivative value of input image in y direction

The evaluation vector generation unit **7** inputs the edge normal direction vector of the input image from the edge extraction unit **6**, and outputs an evaluation vector of the input image defined by the following two formulas.

Formula 11

Length normalized vector of input image

$$\vec{J}=(J_X, J_Y)=\frac{\vec{I}}{|\vec{I}|}$$

Formula 12

When assumed to be a threshold (for fine edge removal), the evaluation vector $\vec{K}$ of the input image is:

$$\text{if } |\vec{I}| \geqq a$$

$$\vec{K}=(K_X,K_Y)=(\cos(2\beta), \sin(2\beta))=(2J_X^2-1,2J_XJ_Y)$$

else

$$\vec{K}=\vec{O}$$

The input image processing part **200** differs from the template image processing part **100** only in the fact that normalizing processing of division by "n" is not performed. In other words, evaluation by the even-numbered times angle, the normalizing processing to 1 in length, and the noise removal processing are performed in the same way as in the template image processing part **100**.

Next, a structure subsequent to the evaluation vector generation unit **7** will be described. As shown in FIG. **1**, in the input image processing part **200**, the evaluation vector of the input image that is output from the evaluation vector generation unit **7** is subjected to Fourier transformation by the orthogonal transformation unit **8**, and is output to the compression unit **9**.

The compression unit **9** compresses the evaluation vector that has been subjected to Fourier transformation, and outputs the result to the multiplication unit **10**. Herein, the compression unit **9** compresses the object to be processed to the same frequency band as the compression unit **4** (e.g., halves on the low frequency side in the x and y directions, respectively, in this embodiment).

The compression unit **9** is, of course, omitted when the data amount is small, or when high-speed processing is not required, and the compression unit **9** is likewise omitted when the compression unit **4** is omitted in the template image processing part **100**.

Next, the multiplication unit **10** and other construction subsequent to this will be described. When the processing in the template image processing part **100** and in the input image processing part **200** is completed, the multiplication unit **10** inputs a Fourier transformation value of each evaluation vector of the template and inputs images from the recording unit **5** and the compression unit **9**.

Thereafter, the recording unit **5** performs a product-sum-calculation according to Formula 9, and outputs the result (i.e., the Fourier transformation value of the similarity value L) to an inverse orthogonal transformation unit **11**.

The inverse orthogonal transformation unit **11** subjects the Fourier transformation value of the similarity value L to inverse Fourier transformation, and outputs the map L(x,y) of the similarity value L to a map processing unit **12**. The map processing unit **12** extracts a high-value point (peak) from the map L(x,y), and outputs its position and its value. The map processing unit **12** and the construction subsequent to this is freely arranged if necessary.

Next, a processing example by the template image of FIG. **2** will be described with reference to FIG. **4** and FIG. **5**. If the input image is as shown in FIG. **4**(*a*), the edge extraction unit **6** extracts an edge component in the x direction as shown in FIG. **4**(*b*), and extracts an edge component in the y direction as shown in FIG. **4**(*c*).

As a result of the aforementioned processing, a similarity value map L(x,y) shown in FIG. **5**(*a*) is obtained. Herein, the front end of the arrow indicated as the "maximum value" is a peak of this map, and, as is apparent from a comparison with the input image of FIG. **5**(*b*), it is understood that the correct point is clearly recognized at only one point.

In the conventional technique, the calculation must be performed by the number of times of the product, i.e., 2AB in order to successively scan the template image on input images and to obtain $\boxed{\rho_{\gamma d}}$ Formula 1 at each position, wherein the size of the input image is $A(=2^{\gamma})$ and the size of the template image is B. Herein, the number of calculations is evaluated by the number of times of the product with high calculation costs.

In contrast, in this embodiment, FFT is performed twice by the orthogonal transformation unit **3** and **8**, the product sum calculation is then performed by the multiplication unit **10**, and inverse FFT is performed once by the inverse orthogonal transformation unit **11**. The number of calculations is merely the number of times of the product of $3\{(2\gamma-4)A+4\}+2A$.

In a comparison of the number of calculations therebetween, the number of calculations of the product according to this embodiment is about 1/100 of the number of calculations of the product according to the conventional technique, if $A=256\times256=2^{16}$, and $B=60\times60$. As a result, unusually high-speed processing is carried out.

The discrete correlation theorem of Fourier transformation cannot be used in such a nonlinear formula as Formula 1 of the conventional technique. Therefore, in the conventional technique, processing for the template image cannot be performed prior to that for the input image as shown in FIG. **1** of this embodiment. In other words, in the conventional technique, both the template image and the input image must be processed simultaneously. Also in this respect, the processing speed in this embodiment is higher than that in the conventional technique.

(Embodiment 2)

In this embodiment, a conjugate compression unit **13** and a conjugate restoring unit **14** are added to the elements of FIG. **1** as shown in FIG. **9**. The conjugate compression unit **13** further halves the Fourier transformation value of the evaluation vector of the template image that has been read from the recording unit **5** by use of complex conjugate properties of Fourier transformation.

This respect will be described. The following formula is established for the spectrum obtained by real number Fourier transformation.

$$\tilde{A}(u,v)=\tilde{A}(-u,-v)^* \quad \text{Formula 13}$$

Formula 15

$$\tilde{V}_X(u,v)=\sum_{i=a}^{b}\tilde{V}_{Xi}(u,v)$$

$$\tilde{V}_Y(u,v)=\sum_{i=a}^{b}\tilde{V}_{Yi}(u,v)$$

wherein the size range is a b.

The similarity value formula that is linear before being subjected to Fourier transformation is still linear after being subjected thereto. Therefore, the position of the addition unit **16** can be changed from the First Example to the Second Example, for example.

Thereby, an object to be processed by the addition unit **16** is reduced more than in the First Example because the object is compressed by compression unit **4**. Therefore, processing speed is improved.

(Embodiment 4)

Referring now to FIGS. **15** and **16**, Embodiment 4 discloses an efficient technique for enhancing the value of the maximum point of the similarity value map described in embodiments 1 and 2 into a stronger peak value.

Generally, in the similarity value map, a peak appears in a part overlapping the template image. In this embodiment, a peak pattern "p" around and including a maximum point is used as a filter for the similarity value map. The value of a part similar to the peak pattern in the similarity value map is amplified.

As shown in FIG. **15**, in this embodiment, a peak pattern processing part **300** is added to the structure of FIG. 1 showing embodiment 1.

FIG. **16** shows a mask for this peak pattern. As indicated in FIG. **16**, in this peak pattern, normalization is made to set an average value at 0.

In the peak pattern processing part **300**, an orthogonal transformation unit **17** subjects this peak pattern to Fourier transformation, and a compression unit **18** compresses a Fourier transformation value before recording compressed data in a recording unit **19**.

Since a mask is used, the similarity value formula is established not by Formula 8 but by the following formula 16 that reflects the mask.

Formula 16

$$\tilde{V}_X(u,v)=\sum_{i=a}^{b}\tilde{V}_{Xi}(u,v)$$

$$\tilde{V}_Y(u,v)=\sum_{i=a}^{b}\tilde{V}_{Yi}(u,v)$$

wherein the size range is a b.

$$\tilde{M}(u,v)=\tilde{L}(u,v)\tilde{P}^*$$

$\tilde{P}$: Peak pattern low frequency spectrum

L(u,v): Similarity value before filtering

M(u,v): Similarity value after filtering

The multiplication unit **10** reads data from the recording unit **5**, the recording unit **19**, and the compression unit **9**, then performs a product-sum-calculation, and outputs the Fourier transformation value of the similarity value corrected by the peak pattern.

A peak pattern filter can filter the similarity value map L according to the following formula, but, if so, a large amount of product sum calculations will be inefficiently needed.

$$M(x,y)=\sum_{l}\sum_{m}p(l,m)L\boxed{x,l,y+m)}$$ Formula 17

In contrast, in this embodiment, simple, accurate processing is performed according to Formula 16 without performing a large amount of calculations like Formula 17.

Therefore, according to this embodiment, the peak point of the similarity value map is efficiently amplified. Additionally, a part similar to the template is clearly and stably detected from the input image while reflecting the peak pattern.

(Embodiment 5)

In this embodiment, a pixel mean in the range of the template image as well as the similarity value between the edge of the input image and the edge of the template image is added to a similarity judgment.

This structure is shown in FIG. 17. Like FIG. **15**, a mask pattern processing part **400** is added to the structure of FIG. 1 of Embodiment 1.

However, the structure of FIG. 17 differs from that of FIG. **15** in that the mask pattern processing part **400** is used, not to input a peak pattern, but to input a template image. Also, a mask pattern generation unit **20** is provided for generating a mask pattern that depends on this image.

Like FIG. **15**, the output of the mask pattern generation unit **20** is subjected to Fourier transformation by the orthogonal transformation unit **21**. The result is then compressed by the compression unit **22**, and the compressed data is recorded in the recording unit **23**.

Further, since a mask is used, the similarity value formula is expressed not as Formula 8 but as the following formula that reflects the mask.

$$Q(x,y)=L(x,y)+\sum_{l}\sum_{m}q(l,m)I(x+l,y+m)$$ Formula 18

Q(x,y): Pixel-average-added similarity value

q(l,m): Mask pattern

L(x,y): Similarity value before filtering

I(x,y): Input image data

For the same reason mentioned in Embodiment 4, a large amount of product sum calculations is inefficiently needed if multiplication is performed in this way.

Formula 19 is obtained by subjecting this to Fourier transformation, whereby the calculation is performed very simply.

$$\tilde{Q}(u,v)=\tilde{L}(u,v)+\tilde{q}^*(u,v)\tilde{I}(u,v)$$ Formula 19

The multiplication unit **10** performs a product-sum-calculation according to Formula 19.

Next, the relationship between the template image and the mask pattern is described with reference to FIG. **18**. Herein, in order to add a pixel mean in the range of the template image to a similarity judgment, the mask pattern generation unit **20** generates a mask pattern as shown in FIG. **18**(*b*) for a template image as shown in FIG. **18**(*a*)▯

In greater detail, in the template image of FIG. **18**(*a*), a value of 1/N is set at each point of the inner part (inside the circle) whose pixel mean is to be calculated, and a value of 0 is set at all other points. N is the number of points in the inner part, and the result of addition of the values of all points of the mask pattern is 1.

According to this embodiment, a mean of pixel values inside the image can also be added to the similarity value, and a specified object is extracted from the input image more accurately and more efficiently.

A mean of a square value of each pixel is calculated such that data in which each pixel of the input image is squared by the input image processing part is formed, and the same processing is applied thereto.

Therefore, a distributed value as well as a mean within a range is efficiently calculated.

(Embodiment 6)

Referring to FIG. 19, Embodiment 6 discloses a technique by which a bilaterally symmetric image with respect to a template image is efficiently processed. In addition to the structure of FIG. **1** of Embodiment 1, a symmetric vector generation unit **24** is provided between the recording unit **5** and the multiplication unit **10**. As in Embodiment 1, Formula 8 is used as the similarity value formula in this embodiment.

Referring now to FIG. **20**(*a*), a description is given of how to treat a bilaterally symmetric template image. For example, if the template image of FIG. **20**(*a*) is an original image, a template image in which the original image has been bilaterally reversed is shown as in FIG. **20**(*b*).

The relationship between the edge normal direction vectors of these template images is expressed by the following formula 20.

Formula 20

Edge normal direction vector of image resulting from subjecting original template image to bilateral reversal

$$\vec{T}'=(T'x(x,y),T'y(x,y)\square$$

$$T'x(x,y)=-Tx(-x,y)$$

$$T'y(x,y)=Ty(-x,y)$$

The evaluation vector of the template image that has been bilaterally reversed is expressed by the following formula 21.

$$\vec{W}=(Wx(x,y),Wy(x,y))\text{: Evaluation vector of }\vec{T}'$$

$$\vec{V}=(Vx(x,y),Vy(x,y))\text{: Evaluation vector of }\vec{T}$$

$$Wx(x,y)=2T'x^2-1=2(-Tx(-x,y))^2-1=2Tx(-x,y)^2-1=Vx(-x,y\square$$

$$Wy(x,y)=2T'xT'y=2(-Tx(-x,y))Ty(-x,y)=-2Tx(-x,y)Ty(-x,y)=-Vy(-x,y\square \qquad \text{Formula 21}$$

Concerning Fourier transformation, because of the relation of Formula 22, Formula 23 is obtained by applying Formula 22 to Formula 21.

$$f(x)=g(-x)\rightarrow\tilde{f}(u)=\tilde{g}(-u) \qquad \text{Formula 22}$$

$$\tilde{W}_X(u,v)=\tilde{V}_X(-u,v)$$

$$\tilde{W}_Y(u,v)=-\tilde{V}_Y(-u,v) \qquad \text{Formula 23}$$

In detail, the evaluation vector of the template image that has been bilaterally reversed is easily generated by, for example, reversing the positive and negative of the evaluation vector of the original template image.

Therefore, the evaluation vector of the template image that has been bilaterally reversed is obtained merely by allowing the symmetric vector generation unit **24** to apply Formula 23 to the evaluation vector of the original template image of the recording unit **5** in FIG. **19**.

When simply assumed, there is no need to perform complex processing, such as a procedure in which the image of FIG. **20**(*b*) is generated from the image of FIG. **20**(*a*), and the evaluation vector is again calculated from the image of FIG. **20**(*b*).

Thereby, the evaluation vector of the template image that has been bilaterally reversed is generated without direct calculations, and processing speed is improved. Additionally, recording capacity is saved because the need to purposely store the template image that has been bilaterally reversed is obviated.

(Embodiment 7)

Referring now to FIG. **22**(*b*), in embodiment 7, eye/eyebrow extraction processing is added to the face extraction processing described in Embodiment 3. Eyes/eyebrow candidate range is roughly extracted from the input image of FIG. **22**(*a*) according to the processing described in Embodiment 3.

Point biserial correlation coefficient filters shown in FIG. **23**(*a*) through FIG. **23**(*d*) are applied to each point of the image of this eye/eyebrow candidate range, a map of point biserial correlation values is then formed. Points where the correlation value in the map are high are set as an eye center point **3002** and as an eyebrow center point **3003**, respectively.

The point biserial correlation coefficient η is defined by the following formula (reference; Multivariate Analysis Handbook, page 17, Modern Mathematics).

$$\eta=\frac{\overline{x_1}-\overline{x_2}}{S}\sqrt{\frac{n_1}{n}\left(1-\frac{n_1}{n}\right)} \qquad \text{Formula 24}$$

Overall range: addition of 1st range to 2nd range

n_1: Number of pixels of 1st range

n: Number of pixels of overall range

$\overline{x_1}$: Average brightness level of 1st range

$\overline{x_2}$: Average brightness level of 2nd range

S: Standard deviation of overall range

Value in $\sqrt{}$ is constant when mask size is fixed.

FIG. **23**(*a*) through FIG. **23**(*d*), FIG. **23**(*a*) show the positional relationships of all ranges. FIG. **23**(*b*) shows an overall range mask. FIG. **23**(*c*) shows a 1st range mask. FIG. **23**(*d*) shows a 2nd range mask.

If the filter shape according to this point biserial correlation coefficient is formed as shown in FIG. **23**(*a*), it is expected that the eyebrow center **3002** and the eye center **3003** are extracted as shown in FIG. **22**(*c*).

Next, filter processing according to the point biserial correlation coefficient will be described.

First, main components of Formula 24 are expressed by the following formula 25.

$$\overline{x_1}=\Sigma I(x+i,\ y+j)M1(i,\ j)$$

$$\overline{x_2}=\Sigma I(x+i,\ y+j)M2(i,\ j)$$

$$\bar{x}=\Sigma I(x+i,\ y+j)Ma(i,\ j)$$

$$\overline{x^2}=\Sigma J(x+i,\ y+j)Ma(i,\ j) \qquad \text{Formula 25}$$

wherein□

$$J(x,\ y)=I^2(x,\ y)$$

$$\overline{x_1}-\overline{x_2}=\Sigma I(x+i,y+j)(M1(x,y)-M2(x,y))$$

M1: 1st range mask
M2: 2nd range mask
Ma: Overall range mask
I(x,y): Each pixel value of input image

The following formulas 26–28 are obtained by subjecting each component to Fourier transformation.

$$(\tilde{\overline{x_1}}-\tilde{\overline{x_2}})=\tilde{I}(\tilde{M}_1-\tilde{M}_2)^* \qquad \text{Formula 26}$$

$$\tilde{\overline{x}}=\tilde{I}\tilde{M}_a^* \qquad \text{Formula 27}$$

$$\tilde{\overline{x^2}}=\tilde{J}\tilde{M}_a^* \qquad \text{Formula 28}$$

wherein

$$J(x,\ y)=I^2(x,\ y)$$

In order to perform these processings, the structure of FIG. **21** is formed, for example. First, each mask of the overall range, the 1st range, and the 2nd range is subjected to Fourier transformation by the orthogonal transformation unit **51** through **53**.

An input image and a result of the face extraction described in Embodiment 3 are input to the eye/eyebrow candidate range extraction unit **54** through the map processing unit **12**. Based on these inputs, the eye/eyebrow candidate range extraction unit **54** extracts only the eye/eyebrow candidate range shown in FIG. **22**(*b*) from FIG. **22**(*a*). Data concerning this eye/eyebrow candidate range is subjected to Fourier transformation by an orthogonal transformation unit **55** without any changes. The result is then squared by a square unit **56**, and is subjected to Fourier transformation by an orthogonal transformation unit **57**.

Thereafter, data shown in Formula 27 is input through a multiplication unit **58** to an inverse orthogonal transformation unit **62** precedent to a η map forming unit **65**. Likewise, data shown in Formula 26 is input to an inverse orthogonal transformation unit **63** through a multiplication unit **60**, and data shown in Formula 28 is input to an inverse orthogonal transformation unit **64** through a multiplication unit **61**. The input data is subjected to inverse Fourier transformation by the inverse orthogonal transformation unit **62** through **64**, and is output to the η map forming unit **65**.

Thereafter, the η map forming unit **65** performs a calculation according to Formula 24 when receiving the data from the inverse orthogonal transformation unit **62** through **64**, and outputs a map η(x,y) of the point biserial correlation coefficient.

The eye/eyebrow center extraction unit **66** extracts two points having high values from the map η(x,y) output by the η map forming unit **65**, and outputs them as the eyes center and an eyebrow center, respectively.

In this structure, multiplication must be performed roughly 15×15×N=225N times, wherein "15×15" (pixels) is the filter size of FIG. **23**(*a*), and N is the number of pixels of the input image.

In contrast, according to this embodiment, the number of product calculations is roughly N+[(2γ−4)N+4]×5+12N+N+N=5N(2γ−1)+20 times. For convenience, the calculation of "√" is assumed to be equal to one multiplication processing.

That is, (calculation amount of this embodiment)<(calculation amount of the conventional technique) under the condition that γ is 22 or less.

Usually, a huge image in which N is 222 or more is not used. Therefore, it is understood that the image processing of this embodiment is smaller in the number of calculation times than that of the conventional processing, and is performed faster than that of the conventional processing.

Thus, according to this embodiment, the point biserial correlation coefficient filter processing is more efficiently performed.

The positions of other face parts, such as eye comers, mouth edges, nostrils, and irises, are calculated by variously changing the masks shown in FIG. **23**(*a*) through FIG. **23**(*d*).

(Embodiment 8)

This embodiment discloses a technique for expanding the function of the face extraction according to Embodiment 3 and extracting a mouth range, which is a facial organ, from a face image.

As described in Embodiment 3 with reference to FIG. **14**, a mouth candidate range shown in FIG. **25**(*b*) is extracted from the input image of FIG. **25**(*a*).

When the extracted mouth candidate range is projected onto the Y-axis (i.e., when the total h of pixel values is plotted along the X-axis), a graph roughly shown in FIG. **25**(*c*) is obtained.

The total h is defined by the following formula 29.

Formula 29

$$h(x,\ y)=\sum_{i=x-w/2}^{x+w/2} I(x+i,\ y)$$

I(x,y): Each pixel value of input image
w: Width of mouth candidate range
h(x,y): Projection value

In order to efficiently obtain this total by use of orthogonal transformation, a mask shown in FIG. **25**(*d*) is prepared. Formula 29 is rewritten like the following formula 30, including this mask.

$$h(x,\ y)=\sum_{i=x-w/2}^{x+w/2} I(x+i,\ y)=\sum_{i,j} m(i,\ j)I(i+x,\ j+y) \qquad \text{Formula 30}$$

m: Mask

When this is subjected to Fourier transformation, the following formula 31 is obtained.

$$\tilde{h}(u,v)=\tilde{m}(u,v)^*\tilde{I}(u,v) \qquad \text{Formula 31}$$

That is, this projection value is obtained by subjecting the input image and the mask pattern to Fourier transformation, thereafter performing the calculation of Formula 31, and subjecting the result to inverse Fourier transformation. Thereby, the map "h(x,y)" of the projection value "h" is obtained.

From the above result, it is desirable to form the structure of FIG. **24**, for example. As shown in FIG. **24**, the input image and the mask pattern are subjected to Fourier transformation by the orthogonal transformation unit **25** and **26**, respectively.

Thereafter, the transformation value is multiplied by the multiplication unit **27**, and is subjected to inverse Fourier transformation by the inverse orthogonal transformation unit **28**. As a result, the map h(x,y) of the projection value is obtained.

correction function determining unit **37** outputs the correction function to the image correction unit **34**.

The horizontal axis of the brightness histogram of FIG. **30** indicates brightness values. It will be understood that only a part of the dynamic range that can express brightness is used. Therefore, the correction function determining unit **37** determines the correction function so as to filly use the dynamic range, and thereby the image correction unit **34** can correct the face image so that the image is easily discerned, or, more specifically, so that it can have abundant gradations in appearance. As a result of this correction, the face image is infallibly easily viewable although there might be a situation in which a part other than the face image is lightened or darkened.

Herein, since the correction function is determined on the basis only of the facial inner image, correction is never misled by a non-face part. Therefore, after correction, it is guaranteed that viewability of the face is improved.

Although FIG. **30** shows the drawing so as to make correction only to the cut-out face image, similar correction is made to the whole input image.

Further, as a feature to be sought by the image feature extraction unit **36**, an index that represents the lightness/darkness of an image, such as brightness, is used as described above. In addition, a chroma average or a hue average may be used.

If the chroma average is used, the correction function determining unit **37** can output, for example, a chroma amplification coefficient to the image correction unit **34**. If the hue average is used, the correction function determining unit **37** can output, for example, a hue rotational angle to the image correction unit **34**.

Herein, a pale face image is more vividly corrected when the chroma average is used as a feature. When the hue average is used, a less reddish face image is corrected to be more reddish. In either case, the face image is made more natural. Additionally, a combination of two or more of brightness, chroma average, or hue average may be used as a feature.

Having described preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention as defined in the appended claims.

What is claimed is:

1. An image processing method comprising the steps of:
inputting a specified image for a template image;
inputting a specified image for an input image;
calculating an edge normal direction vector of said specified image;
generating an evaluation vector from said edge normal direction vector;
normalizing said evaluation vector of said template image by the number of edge normal direction vectors;
subjecting said evaluation vector to orthogonal transformation;
performing a product sum calculation of corresponding spectral data for each evaluation vector that has been subjected to orthogonal transformation;
subjecting a result of said product sum calculation to inverse orthogonal transformation and generating a map of similarity values; and
a formula of said similarity values, said orthogonal transformation, and said inverse orthogonal transformation each have linearity.

2. The image processing method of claim **1**, further comprising the step of:
compressing each evaluation vector that has been subjected to orthogonal transformation so as to reduce a processing amount.

3. The image processing method of claim **1**, wherein for said template image, the steps taken until said evaluation vector that has been subjected to orthogonal transformation is compressed are executed before said input image is input, and storing results thereof.

4. The image processing method of claim **1**, further comprising the step of:
normalizing said evaluation vector with respect to a vector length.

5. The image processing method of claim **1**, further comprising the steps of:
reducing a data amount using complex conjugate properties of orthogonal transformation before performing a product sum calculation; and
restoring said data amount after performing said product sum calculation.

6. An image processing method comprising the steps of:
inputting a specified image for a template image;
inputting a specified image for an input image;
enlarging/reducing said template image to various sizes;
calculating an edge normal direction vector of said specified image;
generating an evaluation vector from said edge normal direction vector;
subjecting said evaluation vector to orthogonal transformation;
subjecting said evaluation vector of each size to addition processing;
performing a product sum calculation of corresponding spectral data for each evaluation vector that has been subjected to orthogonal transformation;
subjecting a result of said product sum calculation to inverse orthogonal transformation and generating a map of similarity values; and
a formula of said similarity values, said orthogonal transformation, and said inverse orthogonal transformation each have linearity.

7. The image processing method of claim **6**, wherein, for said template image, said addition processing of said evaluation vector is carried out after executing said step of compressing each evaluation vector so as to reduce the processing amount.

8. The image processing method of claim **1**, wherein said template image is an image of a typified face.

9. The image processing method of claim **1**, further comprising the steps of:
preparing a peak pattern that makes a peak of said similarity value steep; and
subjecting data of said peak pattern to orthogonal transformation to said product sum calculation.

10. The image processing method of claim **1**, further comprising the steps of:
forming a mask pattern that depends on said template image; and
subjecting data of this mask pattern to orthogonal transformation to said product sum calculation.

11. The image processing method of claim **10**, wherein said mask pattern includes an average of a number of pixels in an image of said template image.

12. The image processing method of claim 1, further comprising the steps of:

for said template image, processing positive and negative signs of said evaluation vector of said original template image; and

generating an evaluation vector of a bilaterally symmetrical image with respect to said original template image, by which said generated evaluation vector is applied to said product sum calculation.

13. The image processing method of claim 8, further comprising the steps of:

generating a map of point biserial correlation coefficients on the basis of an extracted face image; and

responsive to said correlation coefficients, calculating a position of said face part.

14. The image processing method of claim 8, further comprising the steps of:

calculating a distribution of projection values in a y-direction on the basis of said extracted face image by use of said mask pattern;

calculating two maximum points from said distribution; and

outputting a range between said two maximum points as a mouth range.

15. The image processing method of claim 8, further comprising the steps of:

dividing said input image into only said face image and parts other than said face image on the basis of said extracted face image;

embedding a digital watermark only into said face image;

combining said face image into which said digital watermark has been embedded with parts other than said face image to produce a combined result; and

outputting said combined result.

16. The image processing method of claim 8, further comprising the steps of:

dividing said input image into only said face image and parts other than said face image on the basis of said extracted face image;

editing only said face image;

combining said face image after editing with parts other than said face image to produce a combined result; are

outputting said combined result.

17. An image processing apparatus comprising:

a template image processing part operable to input a template image and calculate an edge normal direction vector of said template image, normalize said edge normal direction vector of said template image, generate an evaluation vector from said normalized edge normal direction vector, subject said evaluation vector to orthogonal transformation, and compress said evaluation vector that has been subjected to said orthogonal transformation so as to reduce the processing amount;

an input image processing part operable to input an input image and calculate an edge normal direction vector of said input image, generate an evaluation vector from said edge normal direction vector, subject said evaluation vector to orthogonal transformation, and compress said evaluation vector that has been subjected to said orthogonal transformation so as to reduce the processing amount;

an enlargement/reduction unit operable to enlarge or reduce said template image to various sizes;

a multiplication unit operable to perform a product sum calculation of corresponding spectral data about each evaluation vector that has been subjected to said orthogonal transformation and has been obtained for said template image and said input image;

an addition unit operable to perform addition processing of said evaluation vector of each size; and

an inverse orthogonal transformation unit operable to subject a result of said product sum calculation to inverse orthogonal transformation and further operable to generate a map of similarity values;

said evaluation vector including a component in which an edge normal direction vector of a specified image undergoes even-numbered times angular transformation, and a formula of said similarity values, said orthogonal transformation, and said inverse orthogonal transformation each have linearity.

18. The image processing apparatus of claim 17, wherein said template image processing part includes a recording unit operable to record said evaluation vector that has been compressed to reduce a processing amount and that has been subjected to orthogonal transformation, and a result obtained by compressing said evaluation vector that has been subjected to orthogonal transformation is stored in said recording unit before inputting said input image.

19. The image processing apparatus of claim 17, further comprising:

a conjugate compression unit between said recording unit and said multiplication unit;

said conjugate compression unit operable to reduce the data amount using complex conjugate properties of orthogonal transformation;

a conjugate restoring unit between said multiplication unit and said inverse orthogonal transformation unit; said conjugate restoring unit operable to restore the data amount reduced by use of the complex conjugate properties of orthogonal transformation.

20. The image processing apparatus of claim 17, wherein said addition unit is further operable to perform addition processing of said evaluation vector of said template image after compressing said vector so as to reduce the processing amount.

21. The image processing apparatus of claim 17, further comprising a peak pattern processing unit operable to subject a peak pattern by which a peak of a similarity value is made steep to orthogonal transformation and compress said peak pattern that has been subjected to said orthogonal transformation so as to reduce the processing amount, wherein a result obtained by subjecting data of this peak pattern to said orthogonal transformation is applied to a product sum calculation of said multiplication unit.

22. The image processing apparatus of claim 17, further comprising:

a mask pattern processing part operable to form a mask pattern that depends on said template image and generate data obtained by subjecting data of this mask pattern to orthogonal transformation and by compressing it, wherein a processing result of said mask pattern processing part is applied to a product sum calculation of said multiplication unit.

23. The image processing apparatus of claim 22, wherein said mask pattern includes a mean of a number of pixels inside an image of said template image.

24. The image processing apparatus of claim 17, further comprising:

a symmetric vector generation unit operable to process positive and negative signs of said evaluation vector of an original template image recorded in said recording unit, and further operable to generate an evaluation vector of a bilaterally symmetric image with respect to

said original template image, wherein said evaluation vector generated by said symmetric vector generation unit is applied to a product sum calculation of said multiplication unit.

25. The image processing apparatus of 17, further comprising a map forming unit operable to form a map of a point biserial correlation coefficient on the basis of an extracted face image, and an extraction unit operable to calculate a position of a face part from the formed map.

26. The image processing apparatus of 17, further comprising a maximum point extraction unit operable to calculate a projection value distribution in a y direction by use of a mask pattern on the basis of an extracted face image, and further operable to calculate two maximum points from this distribution, and outputting a range between said maximum points such as a mouth range.

27. The image processing apparatus of 17, further comprising:

a face image cutting-out unit operable to separate an input image into only a face image and parts excluding said face image on the basis of an extracted face image;

a digital watermark embedding unit operable to embed a digital watermark only into the face image; and

an image synthesizing unit operable to combine said face image into which said digital watermark has been embedded with parts excluding said face image and outputting the combined data.

28. The image processing apparatus of 17, further comprising:

a face image cutting-out unit operable to separate an input image into only a face image and parts excluding said face image on the basis of an extracted face image;

an image correction unit operable to edit only said face image; and

an image synthesizing unit operable to combine an edited face image with parts excluding said face image and outputting them.

29. The image processing method of claim 8, further comprising:

cutting out a face image from said input image on the basis of an extracted face image;

extracting a facial inner image from said face image that has been cut out;

calculating a feature that correct said face image on the basis of said extracted face image;

determining a correction function on said basis of said obtained feature; and

applying image correction based on said determined correction function at least onto said face image that has been cut out.

30. The image processing method of claim 29, wherein said feature is a combination of at least two of brightness, chroma average, and hue average.

31. The image processing apparatus of 17, further comprising:

a face image cutting-out unit operable to cut out a face image from said input image on a basis of an extracted face image;

a face internal range extraction unit operable to extract a facial inner image from said face image that has been cut out;

a image feature extraction unit operable to calculate a feature that serves to correct said face image on a basis of said extracted face image;

a correction function determining unit operable to determine a correction function on a basis of said obtained feature; and

a image correction unit operable to apply image correction based on said determined correction function at least onto said face image that has been cut out.

32. The image processing apparatus of claim 31, wherein said feature is a combination of at least two of brightness, chroma average, and hue average.

* * * * *